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SUPPLEMENT TO *THIRTY-FIFTH* PROGRESS REPORT OF THE FIRESTONE TIRE & RUBBER COMPANY ON BATTALION ANTI-TANK PROJECT

UNDER

Contract Nos. DA-33-019-ORD-33
DA-33-019-ORD-1202

ORDNANCE DEPARTMENT PROJECTS
TS4-4020—WEAPONS AND ACCESSORIES
TM1-1540—AMMUNITION

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THE FIRESTONE TIRE & RUBBER COMPANY
Defense Research Division
Akron, Ohio

JUNE 1953

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SECURITY INFORMATION

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SUPPLEMENT TO

THIRTY-FIFTH

PROGRESS REPORT

OF

THE FIRESTONE TIRE & RUBBER CO.

ON

BATTALION ANTI-TANK PROJECT

Contract Nos.
DA-33-019-ORD-33 (Negotiated)
DA-33-019-ORD-1202

RAD Nos. ORDTS 1-12383
ORDTS 3-3955
ORDTS 3-3957
ORDTA 3-3952

THE FIRESTONE TIRE & RUBBER CO.
Defense Research Division
Akron, Ohio

JUNE, 1953

SECRET

ABSTRACT

The penetrating performances of smooth and of fluted cones have been compared under both static and dynamic firing conditions. The test data are presented and discussed.

In order to extend the use of fluted cones to charges of sizes other than the 105mm, a program is planned to determine the effect of size upon the behavior of the penetration cone and charge. The first tests in this program with 75/105 scaled counterparts have been conducted and the results are reported.

The evaluation of various types of bearing systems for possible use in double body projectiles has continued. The tests reported here are for tapered roller bearings. The test procedures and results are presented.

T120 PROJECTILE

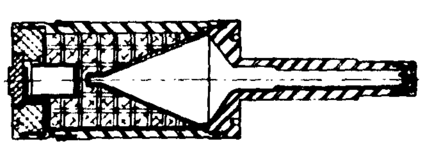
Serrated Liners

Static and Dynamic Penetration Tests of DRD393 item 2 Cones, T138E73 Projectiles

The penetration behavior of T138E73 projectiles, containing DRD393 item 1 cones, was reported in the Supplement to the Twenty-Ninth Progress Report. The results were not satisfactory and when a sample from the lot of ammunition was tested statically the results were very much poorer than had been obtained in earlier static tests. The dynamic and static tests have therefore been repeated although certain minor differences have been introduced. The DRD393 item 1 cone has been replaced by the somewhat better performing item 2 cone and the DRC314 HW9 tee has been replaced by the DRC314HW11 tee. The latter tee does not reduce the penetration as much as does the former. (See Twenty-Sixth and Twenty-Seventh Progress Reports and also the Supplement to the Twenty-Ninth Progress Report).

Nine T138E73 projectiles and nine T138 E57 projectiles were loaded at Picatinny Arsenal, Lot Nos. PA-E-12679 and PA-E-12678 respectively, and were fired alternately from a T137E3 recoilless rifle having a tube rifled 1 turn in 80 calibers against homogeneous armor plate inclined at an obliquity of 59.75°. The firing tests were conducted at Aberdeen Proving Ground. Table I is a modification chart for the T138 E73 projectile. The only difference between the two types of projectiles used in this test is in the cone type. The T138 E73 has a DRD393 item 2 fluted cone, the T138E57 has a conventional DRB398 smooth cone. The T138E57 projectiles used here differed from the standard T138E57 in that these contained the DRC314HW11 tee rather than the DRC314 tee. Therefore, the weight and C.G. location for the two types of projectiles used in this test are identical and are as shown in Table I.

Table I
Physical and Aerodynamic Characteristics
T138E73 Modification
For Use in Tube Rifled 1 in 120 or 1 in 80



Part	Drawing No	Material	Weight (Lb)
Band, Rotating	DRB360	Gilding metal, annealed	0.25
Body	DRC321	Steel WD1045	7.41
Cap, Tee	DRA695	Steel WD1030	0.09
Cone	DRD393 item 2	Copper QQ-C-576	0.84
Bushing, Tee Cap	DRA696	Rubber	--
Element, Nose (T222E3)	DRA496		0.03
Pad, shock	DRA461	Felt MIL-F-10954	
Plug, Base (A)	DRA288	Aluminum 24S-T4	0.11
Plug, Base (B)	DRB410	Aluminum 24S-T4	1.03
Ring, "O"	DRA459	Rubber	--
Sleeve, Grommet	DRA492	Nylon FM 3003	--
Strip, Pin	DRA454	Phenolic Laminate	--
Tape	DRA627	Viscose Rayon	
Tee	DRC314 HW11	Steel WD 1030	4.39
Washer	DRA721	Felt	--
Wire, Fuze Assembly	DRA628	Beryllium Copper #24	--
Element, Base for fuze	DRA579	------	.36
Charge, H.E.	----	Comp B, Grade I, JAN-C-401	2.27
			16.78

Total Projectile Weight (calculated)
C.G.: 1.23 calibers from base (5.09 inches)
Axial moment of inertia: 43.0 lb-in² (nominal)
Transverse moment of inertia: 204.0 lb-in² (nominal)

Before testing these projectiles at Aberdeen Proving Ground, ten DRC376 test assemblies were tested at Erie Ordnance Depot. Five of these assemblies contained DRD393 item 2 cones and were fired at 52 rps; the remaining five contained DRB398 smooth cones and were fired at 0 rps. These ten test assemblies were loaded at Picatinny at the same time the test projectiles were loaded and were intended to provide a check on the loading and handling procedures. The penetration data for these ten rounds are presented in Table II. It is evident that each type of cone is behaving properly.

The penetration data for the "gun-firing" or dynamic test are shown in Table III. The performance of both the dynamic and static tests are summarized below.

DRD393 item 2 cone			
	Static	52 rps	18.92 in. H.A.
	Dynamic	59 rps	13.56 in. H.A.
DRD398 Cone			
	Static	0 rps	19.83 in. M.S.
	Dynamic	59 rps	7.58 in. H.A.

Table II
Penetration Data
Static Controls for Dynamic Tests

Round No.	Comp. B lbs.	Rev/Sec	Penetration inches in M.S.	Max. Spread inches	Std. Dev. inches
DRB398 Cone					
Q762	2.53	0	19.38		
Q763	2.57	0	20.12		
Q781	2.53	0	19.12		
Q782	2.54	0	20.31		
Q783	2.53	0	20.31		
			Avg. 19.83	1.19	±.56
DRD393 item 2 Cone					
P50-102	2.55	52	19.18		
P50-103	2.53	52	18.31		
P50-104	2.52	52	18.75		
P50-105	2.54	52	18.75		
P50-111	2.55	52	19.62		
			Avg. 18.92	1.31	±.50

Notes:
1. Rounds assembled in DRC376 test bodies with No. 1 nose rings.
2. Loaded at Picatinny Arsenal, Lot No. PA-E-12687 and PA-E-12688 using Composition B from Holston Lot No. 4-185.
3. Tested at Erie Ordnance Depot using a standoff of 7.5 inches.
4. Dummy base elements (steel) were used to simulate the T208E7 base element.

Table III
Firing Record
Dynamic Penetration Test

Projectiles:	T138E73; P50-112, 114 to 121 incl. T138E57; Q784, 787 to 791, 793, 795, 834
Gun:	T137E3 No. 13
Breech Ring:	22B-330-1
Tube:	22B345E (1/2" Muzzle Counterbore) Rifled 1 turn in 80 calibers 95 inch length.
Target:	7 homo-armor plates, each 1.5 inches thick
Obliquity:	59.75° (536.7 mil elevation on Gunner's Quadrant = 30.25°)

Firing Order	Round Number	Velocity		Penetration (inches)	Hole Size	
		Muzzle	Striking		Vert.	Horiz.
1	Q784	1634	1532	8.94	3.2	2.5
2	P50-112	1640	1538	13.67	3.2	1.8
3	Q787	1639	1537	6.84	3.2	2.6
4	P50-114	1626	1525	13.67	3.0	2.2
5	Q788	1653	1551	6.96	3.2	2.5
6	P50-115	1650	1548	(4.23)	(2.5)	(1.0)
7	Q789	1657	1555	7.46	3.5	2.8
8	P50-116	1643	1541	12.67	3.5	2.4
9	Q790	1621	1519	7.46	3.5	2.5
10	P50-117	1628	1527	15.40	3.5	2.5
11	Q791	1635	1533	7.46	3.8	2.5
12	P50-118	1636	1534	12.04	4.0	1.8
13	Q793	1643	1541	7.46	4.0	2.8
14	P50-119	1626	1525	13.67	3.5	3.5
15	Q795	1656	1554	7.21	3.8	2.5
16	P50-120	1643	1541	13.67	3.5	2.5
17	Q834	1636	1534	8.46	3.8	2.8
18	P50-121	1623	1522	13.67	4.0	2.0
T138E57	Ave.	1641	1540	7.58	3.6	2.6
	Max.	1657	1555	8.94	4.0	2.8
	Min.	1621	1519	6.84	3.2	2.5
T138E73	Ave.	1635	1533	13.56	3.8	2.3
	Max.	1650	1548	15.40	4.0	3.5
	Min.	1623	1522	12.04	3.0	1.8

Notes:
1. Projectile aimed low and shoulder of projectile struck target plate supporting buttress. Values in parentheses not included in averages.

A comparison of these data with the spin rate penetration curves for the two types of cones (Supplement to the Twenty-Ninth Progress Report and the Twenty-Seventh Progress Report) discloses that the penetration of the fluted cone is about 2.5 inches less than expected (assuming a 15% loss due to conversion from mild steel to armor). It is known that the DRC314HW11 tee provides barely enough free space for the proper collapse of the cone when the projectile is statically fired. It may be that the tee is pushed rearward upon impact with the target and reduces the free space just enough to cause the observed interference. At 59 rps the smooth DRB

398 cone is expected to penetrate only 7.5 to 8.0 inches of mild steel (or armor since at this low a performance level no difference in the stopping power of mild steel and homogeneous armor is experienced) indicating that the T138E57 performed normally. Additional static and dynamic tests are required to determine the comparative effect upon requirements for internal tee configuration.

Although it would have been preferable to have had a still higher percent compensation the penetration measured in this test at 60 rps is as high as has ever been obtained with a T138 projectile regardless of the spin at which it was fired. This test provides the first full scale demonstration that spin compensation by fluted cones can be obtained in actual projectile firings.

Scaling Studies

In extending the use of fluted cones to charges of sizes other than 105mm it is necessary to know the effect of size upon the behavior of the penetration cone and charge. Since a considerable amount of work has been done in this laboratory with DRB398 smooth and DRD367 fluted cones, it is planned to evaluate similar charges scaled down in the ratio of 75/105 and 90/105. The first tests with 75/105 size charges have been completed.

The 75/105 scaled counterpart of the DRB398 cone and DRC376 test assembly consists of a DRB706 cone and DRC505 test assembly (No. 2 nose ring). Fig. 1 shows the cone and Fig. 2 shows the cone and charge assembly. The 75/105 version of the DRD267 cone is DRB703, shown in Fig. 3. The DRD267 cones are made by coining the flutes into drawn DRB398 cones. The DRB706 smooth cones and the DRB703 fluted cones were made by cutting off DRB398 and DRD267 cones at the appropriate base diameter and by machining out the inside cone surface to the specified final wall thickness. A second series of the 75/105 cones (DRB705) was also made and tested. This cone differs from the DRB703 in that the wall thickness

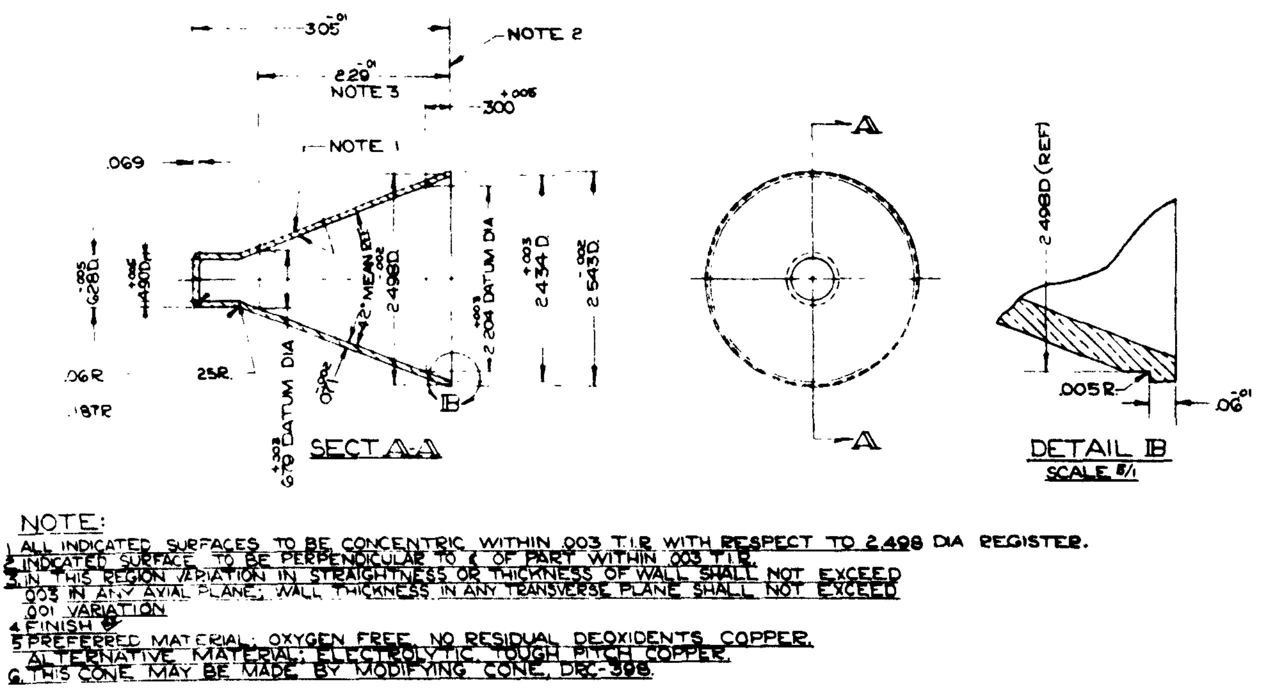


Fig. 1. DRB706 Cone.
Scaled Counterpart of DRB398 Cone.

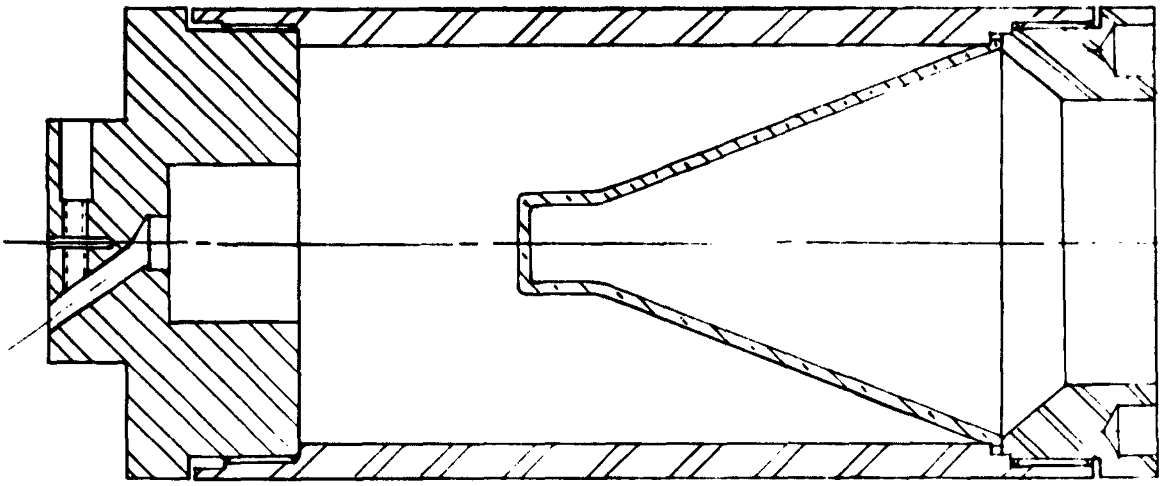


Fig. 2. DRC505 Penetration Test Assembly.
Scaled Counterpart of DRC376 Test Assembly.

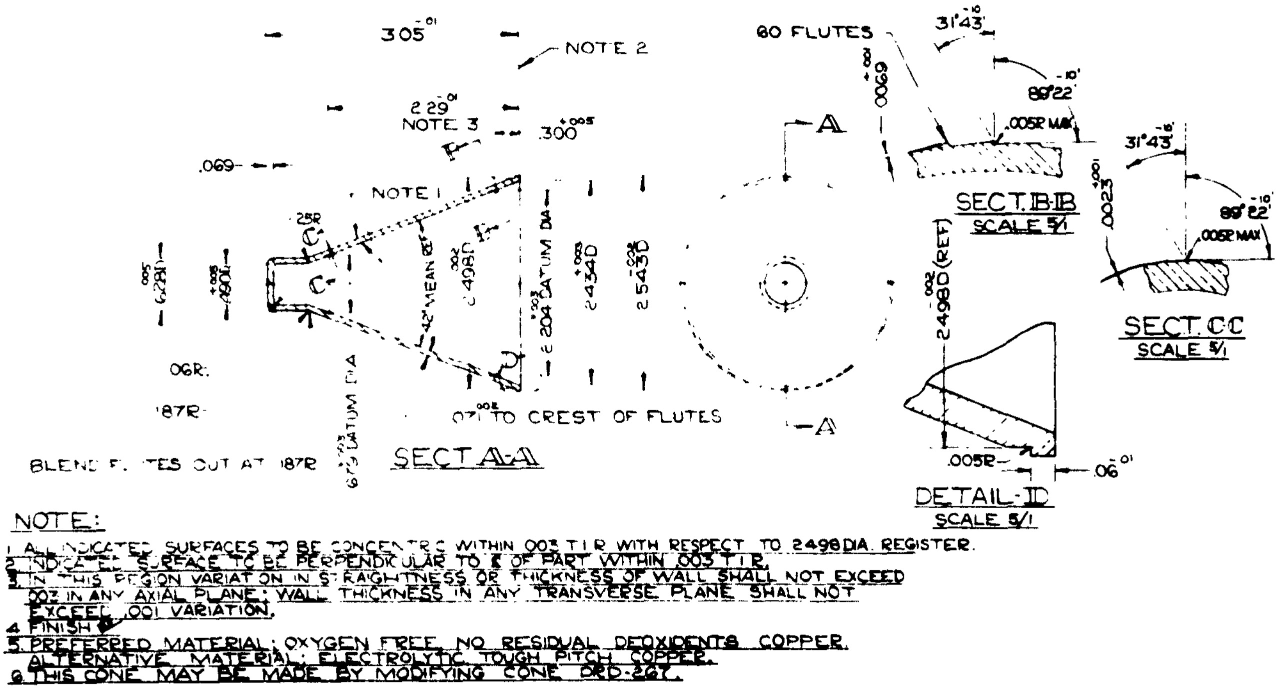


Fig. 3. DRB703 Cone.
Scaled Counterpart of DRD267 Cone.

is the same as that of the parent DRB398 cone, namely, $.100^{+.005}$ in. In this scaling study, then, we have completed the stand-off study of the DRB706 smooth cone, and the spin rate study for the DRB706 cone and also for the DRB703 and DRB705 fluted cones. The data are to be compared with the corresponding data for the 105mm charge.

The penetration behavior of DRB398 smooth and DRD267 fluted cones has been described in earlier reports. For the DRB398 smooth cone the effect of stand-off is shown in Fig. 6 of the Thirty-Second Progress Report. The effect of rotation for each type of cone is shown on page 5 of the Supplement to the Twenty-Sixth Progress Report. It is assumed that at its optimum spin rate the standoff penetration behavior of the fluted cone will be essentially the same as that of the parent smooth cone, DRB398.

The inspection data for the three series of cones are shown in Tables IV to VI, and the penetration data in Tables VII to X.

The effect of size upon standoff is shown in Fig. 4. In accordance with the established theory of the behavior of shaped charges the penetration at any given standoff distance is linear with the effective size of the cone, in this case the diameter of the charge. The usually chosen standoff in these 105mm studies has been 7.50 inches which scales down to 5.35 inches in the corresponding 75mm size.

The effect of rotation upon the penetration of the 75mm and 105mm scaled, unfluted cone charges is shown in Fig. 5. As should be expected the smaller cone is affected less by rotation than is the larger cone and at spin rates above 35 rps there is no important difference in the depth of penetration achieved by the two rounds.

The effect of size upon the optimum spin rate can be obtained from a comparison of the optimum spin rate for the DRB703 fluted cone (Fig. 6) and the DRD 267 cone of Fig. 2 of the Supplement to the Twenty-Sixth Progress Report .

The data are summarized below:

	γ_0	P(opt)	% Comp.	$r\gamma_0$
DRB703	42	13.8	95	52.5
DRD267	25	20.8	100	43.8

Using the relationship $\dfrac{(\gamma_0)_A}{(\gamma_0)_B} = \left(\dfrac{D_B}{D_A}\right)^x$

the value of the "scaling factor" x is 1.54

A similarly defined scaling factor was reported in the Supplement to the Thirty-Fourth Progress Report for relating the performance of the DRD78 Firestone cone with that of a somewhat similar 57mm cone reported in Carnegie Institute of Technology report CIT-ORD-R29. In this case the value of x was found to be 1.32. Considering the approximations involved the two values of x , 1.32 and 1.54, are in gcod agreement.

From theoretical considerations it may be deduced that the optimum performance of different sized cones should be invariant in the quantity ωd (or $\gamma_0 d$). That is, γ_0 d=constant, for geometrically similar cones. Values of γ_0 d for the two series of cones are shown below:

	γ_0	d	$\gamma_0 d$	$(\gamma_0 d)_A/(\gamma_0 d)_B$
A. DRD78	-85	3.38	287	0.78
B. CIT 57mm	-225	1.63	367	
A. DRD267	25	3.5	87.5	0.833
B. DRB703	42	2.5	105	

From these two experiments it appears that the ratio $\dfrac{(\gamma_0 d)_A}{(\gamma_0 d)_B}$ where the size of B is smaller than A is approximately 0.8 ± .05 rather than 1.0.

The effect of wall thickness is also shown in Fig. 6. The DRB703 and DRB 705 cones differ only in the wall thickness. Their external fluted surfaces are as nearly identical as one set of dies can reproduce them. Yet the DRB703 cones (.070-inch wall) compensated at 42 rps while the DRB705 cones (.107-inch wall) did not show any compensation. For 105mm cones fluted on the external surface only the optimum spin rate has been found to be inversely proportional to the square of minimum wall thickness. On this basis the optimum performance of the DRB705 cones would be 42 x$\left(\dfrac{.0636}{.1015}\right)^2$= 16 rps. It is evident that the optimum spin rate for these cones is not 16 rps. Further studies of the effect of cone wall thickness are indicated.

Table IV
Inspection Data
75 mm. DRB706 Smooth Cones

Cone No.	Wall Thickness (in.)			Maximum Variation in Wall Thickness (in.)		Max. Wall Waviness (in.)		Concentricity T.I.R.[1,2]		
	Max.	Min.	Avg.	Trans.	Long.	O.D.	I.D.	Base Datum	Apex Datum	Cone Tip in Ass'y
Specification DRB-706 Cones	.071	.069		.001	.003	.0030	.0030	.0030	.0030	.015 (Nominal)
FS1023	.078	.071	.0741	.001	.007	.0030	.0050	.0020	.0030	.003
FS1024	.080	.073	.0763	.002	.007	.0020	.0050	.0010	.0020	.002
FS1025	.080	.073	.0766	.001	.007	.0020	.0030	.0010	.0020	.006
FS1026	.077	.071	.0739	.001	.006	.0020	.0040	.0010	.0010	.007
FS1027	.078	.071	.0751	.002	.007	.0020	.0040	.0020	.0010	.004
FS1028	.082	.071	.0763	.002	.011	.0020	.0050	.0040	.0020	.004
FS1029	.077	.070	.0736	.001	.007	.0020	.0040	.0020	.0010	.013
FS1030	.076	.070	.0731	.001	.006	.0030	.0040	.0030	.0020	.004
FS1031	.080	.071	.0758	.001	.009	.0030	.0050	.0030	.0040	.004
FS1032	.077	.070	.0738	.001	.006	.0040	.0050	.0030	.0020	.005
FS1033	.075	.068	.0718	.001	.006	.0040	.0030	.0020	.0020	.003
FS1034	.076	.069	.0726	.001	.007	.0030	.0040	.0020	.0010	.006
FS1035	.074	.070	.0723	.001	.004	.0020	.0030	.0020	.0020	.006
FS1036	.076	.072	.0736	.001	.004	.0030	.0040	.0020	.0010	.003
FS1037	.073	.071	.0718	.001	.002	.0010	.0030	.0010	.0010	.005
FS1038	.078	.072	.0746	.002	.006	.0030	.0030	.0010	.0020	.003
FS1039	.078	.071	.0744	.001	.007	.0030	.0030	.0020	.0010	.010
FS1040	.076	.072	.0738	.001	.004	.0020	.0020	.0010	.0020	.003
FS1041	.075	.071	.0731	.001	.004	.0020	.0020	.0010	.0010	.002
FS1042	.078	.073	.0750	.001	.005	.0020	.0030	.0020	.0020	.006
FS1043	.078	.072	.0741	.003	.006	.0030	.0030	.0040	.0030	.006
FS1044	.074	.070	.0718	.001	.004	.0020	.0030	.0030	.0010	.011
FS1045	.078	.071	.0743	.002	.006	.0010	.0050	.0030	.0020	.003
FS1046	.073	.070	.0713	.001	.003	.0020	.0040	.0020	.0020	.002
FS1047	.078	.072	.0751	.001	.006	.0020	.0040	.0030	.0010	.004
FS1048[3]	.080	.075	.0722	.002	.005	.0020	.0050	.0020	.0020	Note 3
Avg.	.0771	.0712	.0739	.0013	.0058	.0024	.0038	.0021	.0018	.0050
Std. Dev.	±.0028	±.0014	±.0017	±.0002	±.0018	±.0008	±.0009	±.0009	±.0008	±.0028

Notes:
1. Lower datum is .484 inch above base; upper datum is 2.29 inches above base.
2. The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.
3. Held for display.

Table V
Inspection Data
DRB703 Cones

Round No.	Average Flute Depth Outside (in.)		Avg. Wall Thickness at Thickest Section of Flute Profile (in.)		Maximum Variation in Wall Thickness (in.)		Max. Wall Waviness Betw. Datums Inside	Datum Diameters		Concentricity T.I.R.[1,2]		
	Base Datum	Apex Datum	Base Datum	Apex Datum	Transverse	Longitudinal		Base	Apex	Base Datum	Apex Datum	Cone Tip in Ass'y
Specification DRB-703 Cones	.0064	.0023	.071$^{-.002}$	.071$^{-.002}$	.001	.003	.003	2.200	.8310	.0030	.0030	.015 max.
P60-265[3]	.0069	.0019	.0683	.0662	.003	.005	.005	2.209	.828	.0020	.0030	----
P60-266	.0067	.0019	.0688	.0655	.003	.007	.005	2.217	.830	.0010	.0020	.010
P60-267	.0063	.0018	.0710	.0680	.002	.004	.004	2.213	.822	.0010	.0030	.002
P60-268	.0069	.0019	.0688	.0660	.002	.004	.004	2.218	.830	.0010	.0020	.010
P60-269	.0069	.0019	.0702	.0672	.003	.005	.005	2.218	.833	.0020	.0020	.004
P60-270	.0069	.0019	.0698	.0675	.001	.003	.003	2.210	.837	.0010	.0020	.011
P60-271	.0068	.0019	.0688	.0678	.002	.003	.003	2.221	.840	.0010	.0020	.006
P60-272	.0069	.0019	.0715	.0708	.001	.002	.002	2.225	.837	.0010	.0010	.004
P60-273	.0068	.0019	.0715	.0698	.001	.003	.003	2.214	.831	.0010	.0020	.011
P60-274	.0068	.0019	.0700	.0690	.002	.002	.002	2.221	.830	.0010	.0020	.001
P60-275	.0069	.0019	.0705	.0683	.001	.003	.003	2.224	.833	.0010	.0020	.004
P60-276	.0068	.0019	.0705	.0683	.002	.004	.004	2.216	.835	.0010	.0020	.010
P60-277	.0069	.0019	.0708	.0688	.003	.003	.003	2.214	.829	.0030	.0050	.008
P60-278	.0069	.0019	.0690	.0668	.001	.003	.003	2.219	.834	.0010	.0040	.004
P60-279	.0069	.0019	.0705	.0680	.002	.004	.003	2.209	.822	.0020	.0010	.005
P60-280	.0068	.0019	.0702	.0675	.001	.003	.004	2.220	.832	.0020	.0030	.002
P60-281	.0068	.0019	.0701	.0675	.002	.005	.005	2.224	.830	.0010	.0010	.002
P60-282	.0063	.0019	.0703	.0678	.001	.003	.003	2.226	.834	.0010	.0030	.006
P60-283	.0069	.0019	.0723	.0670	.002	.007	.007	2.222	.831	.0010	.0010	.003
P60-284	.0068	.0019	.0725	.0688	.001	.005	.005	2.220	.830	<.0010	.0010	.008
P60-285	.0068	.0019	.0710	.0670	.002	.006	.006	2.223	.830	.0010	.0010	.007
P60-286	.0068	.0019	.0705	.0673	.001	.004	.004	2.208	.826	<.0010	.0030	.008
P60-287	.0068	.0019	.0707	.0665	.001	.005	.005	2.226	.836	.0010	.0020	.007
P60-288	.0069	.0019	.0705	.0770	.001	.007	.004	2.226	.836	.0010	.0010	.005
P60-289	.0066	.0018	.0715	.0770	.001	.006	.005	2.230	.838	.0010	.0030	.004
P60-290[3]	.0069	.0019	.0705	.0685	.005	.005	.005	2.227	.838	.0020	.0030	.004
P60-343[3]	.0067	.0018	.0705	.0660	.001	.005	.005	2.212	.830	.0010	.0010	----
AVG.	.0068	.0019	.0704	.0684	.0018	.0043	.0041	2.219	.8329	.0012	.0021	.0018
STD. DEV.	±.0002	----	±.0010	±.0009	±.0009	±.0014	±.0012	±.0060	±.0071	±.0006	±.0010	±.0030

NOTES:

1. The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.
2. Lower datum is .484 inch above the base, upper datum 2.29 inches above base.
3. Held for display.

Table VI
Inspection Data
DRB705 75 mm. Cones

Round No.	Average Flute Depth (in) Outside		Avg. Wall Thickness at Thickest Section of Flute Profile (in.)		Maximum Variation in Wall Thickness (in.)		Maximum Wall Waviness Betw. Datums Inside (in.)	Datum Diameters		Concentricity T.I.R [1,2]		
	Base Datum	Apex Datum	Base Datum	Apex Datum	Transverse	Longitudinal		Base	Apex	Base Datum	Apex Datum	Cone Tip in Ass'y
Specification DRB-705 Cones	$.0069^{+.001}$	$.0023^{+.001}$	$.100^{+.005}$	$.100^{+.005}$	.001	.003	.003	2.215	.828	.0030	.0030	.015 (Max)
P60-317	.0067	.0019	.1070	.1025	.002	.006	.006	2.229	.836	.002	.004	.011
P60-318	.0066	.0019	.1110	.1058	.003	.006	.006	2.228	.834	.003	.004	.006
P60-319	.0067	.0019	.1102	.1045	.001	.006	.006	2.228	.833	.002	.003	.001
P60-320	.0068	.0018	.1108	.1050	.002	.006	.006	2.226	.835	.002	.001	.008
P60-321	.0067	.0019	.1098	.1045	.002	.007	.007	2.228	.834	.002	.004	.013
P60-322	.0062	.0018	.1105	.1058	.001	.005	.005	2.228	.835	.001	.002	.013
P60-323	.0068	.0019	.1085	.1030	.002	.006	.006	2.225	.834	.001	.001	.009
P60-324	.0067	.0019	.1098	.1040	.002	.007	.007	2.223	.834	.001	.002	.005
P60-325	.0066	.0018	.1085	.1042	.002	.005	.005	2.228	.834	.001	.002	.005
P60-326	.0069	.0019	.1093	.1035	.001	.007	.007	2.230	.838	.001	.003	.004
P60-327	.0068	.0019	.1088	.1033	.002	.007	.007	2.221	.836	.002	.003	.013
P60-328	.0068	.0018	.1090	.1048	.002	.005	.005	2.229	.835	.001	.002	.012
P60-329	.0068	.0018	.1093	.1048	.001	.005	.005	2.228	.836	.001	.001	.004
P60-330	.0068	.0019	.1105	.1048	.001	.007	.006	2.228	.834	.001	.003	.009
P60-331	.0069	.0018	.1083	.1033	.003	.006	.006	2.224	.832	.001	.002	.018
P60-332	.0070	.0019	.1090	.1043	.002	.006	.006	2.227	.837	.001	.002	.009
P60-333	.0068	.0019	.1083	.1040	.002	.006	.006	2.228	.838	.003	.002	.006
P60-334	.0067	.0018	.1095	.1040	.001	.006	.006	2.225	.836	.002	.002	.007
P60-335	.0069	.0019	.1090	.1035	.001	.006	.006	2.227	.830	.003	.002	.006
P60-336	.0066	.0017	.1098	.1043	.002	.006	.006	2.229	.832	.002	.002	.005
P60-337	.0068	.0019	.1093	.1050	.003	.005	.005	2.231	.832	.002	.002	.008
P60-338	.0068	.0018	.1083	.1035	.001	.005	.005	2.226	.836	.003	.003	.008
P60-339	.0069	.0018	.1088	.1048	.002	.005	.005	2.229	.834	.001	.002	.008
P60-340	.0067	.0018	.1073	.1035	.002	.005	.005	2.227	.836	.002	.002	.006
P60-341	.0068	.0018	.1078	.1035	.001	.005	.005	2.226	.834	.002	.001	.009
P60-342 [3]	.0068	.0017	.1090	.1045	.002	.005	.005	2.227	.834	.003	.003	--
P60-345 [3]	.0068	.0019	.1083	.1043	.002	.005	.005	2.225	.840	.002	.002	--
Average	.0068	.0018	.1091	.1042	.0018	.0058	.0058	2.2270	.8348	.0018	.0230	.0081
Std. Deviation	<±.0001	<±.0001	±.0010	±.0008	.0006	±.0007	±.0007	±.0021	±.0020	±.0007	±.0009	±.0031

Notes:

1. The base datum is 0.484 inch above the base: Apex datum 2.29 inches above base.
2. The indicated measurement at each datum is the total indicator runout of the liner's outside surface relative to the register diameter. The difference between the runout at the two datum planes is an indication of the lack of perpendicularity of the register plane and the liner axis.
3. Held for display.

Table VII
Penetration Data
Effect of Standoff
DRB706 75 mm. Cones

Round No.	Comp. B lbs.	Standoff inches	Penetration inches in M. Stl.	Max. Spread inches	Std. Dev. inches
FS1023	.88	5.0	13.50		
FS1024	.88	5.0	14.62		
FS1025	.92	5.0	14.75		
FS1026	.92	5.0	15.50		
			Avg. 14.59	2.00	±.82
FS1027	.88	7.5	15.56		
FS1028	.86	7.5	14.44		
FS1029	.88	7.5	15.56		
FS1030	.88	7.5	14.18		
			Avg. 14.93	1.38	±.73
FS1031	.88	10.0	14.88		
FS1032	.88	10.0	14.94		
FS1033	.90	10.0	15.94		
FS1034	.90	10.0	16.38		
			Avg. 15.54	1.50	±.74

Notes:
1. Cones assembled in DRC505-1 test bodies, plugs and rings (No. 2).
2. Loaded at Ravenna Arsenal, BAT Lot No. 30, with Compostion B from Holston Lot No. 4-1197.
3. All rounds were tested at 0 rev/sec at Erie Ordnance Depot.

Table VIII
Penetration Data
Effect of Rotation
DRB706 75 mm. Cones

Round No.	Comp. B lbs.	Rev/Sec	Penetration inches in M.S.	Max. Spread inches	Std. Dev. inches
FS1023	.88	0	13.50		
FS1024	.88	"	14.62		
FS1025	.92	"	14.75		
FS1026	.92	"	15.50		
			Avg. 14.59	2.00	±.82
FS1035	.90	30	13.00		
FS1036	.90	"	12.06		
FS1037	.88	"	12.50		
FS1038	.88	"	11.62		
			Avg. 12.30	1.38	±.59
FS1039	.88	60	7.69		
FS1040	.86	"	7.25		
FS1041	.88	"	7.18		
			Avg. 7.37	.51	±.27
FS1042	.92	90	6.18		
FS1043	.90	"	6.00		
FS1044	.88	"	5.50		
			Avg. 5.89	.68	±.35
FS1045	.88	120	5.81		
FS1046	.88	"	5.25		
FS1047	.86	"	4.62		
			Avg. 5.23	1.19	±.59

Notes:
1. Cones assembled in DRC505-1 test bodies, plugs and rings (No. 2).
2. Loaded at Ravenna Arsenal, BAT Lot No. 30, with Compostion B from Holston Lot No. 4-1197.
3. All rounds were tested at Erie Ordnance Depot using a standoff of 5.0 inches.

Table IX
Penetration Data
Effect of Rotation
DRB703 75 mm. Cones

Round No.	Comp.B lbs.	Rev/Sec	Penetration inches in M. Stl.	Max. Spread inches	Std. Dev. inches
P60-266	.90	0	9.00		
P60-267	.88	"	9.31		
P60-268	.88	"	8.69		
			Avg. 9.00	0.62	±.31
P60-269	.88	15	11.38		
P60-270	.92	15	10.56		
P60-271	.92	15	9.56		
			Avg. 10.50	1.82	±.92
P60-272	.90	30	12.69		
P60-273	.88	30	11.88		
P60-274	.88	30	13.94		
P60-281	.90	30	13.06		
			Avg. 12.89	2.06	±.86
P60-275	.90	45	13.00		
P60-276	.88	45	13.88		
P60-277	.92	45	14.38		
P60-283	-.88	45	13.44		
P60-284	-.88	45	13.69		
			Avg. 13.68	1.38	±.52
P60-278	.86	60	12.69		
P60-279	.92	60	11.31		
P60-280	.88	60	13.44		
P60-282	.88	60	11.18		
			Avg. 12.16	2.26	±1.10
P60-285	.92	90	7.69		
P60-286	.88	90	8.75		
P60-287	.88	90	7.18		
			Avg. 7.87	1.57	±.86
P60-288	.86	120	5.12		
P60-289	.90	120	7.06		
P60-290	.88	120	5.44		
			Avg. 5.87	1.94	±1.04

Notes:
1. Cones assembled in DRC505-1 test bodies, plugs and rings (No. 2).
2. Loaded at Ravenna Arsenal, BAT Lot No. 30, with Composition B from Holston Lot No. 4-1197.
3. All rounds were tested at a standoff of 5.35 inches. (Scale 75/105 x 7.5 inch).

Table X
Penetration Data
Effect of Rotation
DRB705 75 mm. Cones (.100-inch Wall)

Round No.	Comp.B lbs.	Rev/Sec	Penetration inches in M.Stl.	Max.Spread inches	Std. Dev. inches
P60-332	.90	-30	13.00		
P60-333	.86	-30	12.56		
P60-339	.86	-30	12.81		
			Avg. 12.79	.44	±.22
P60-329	.90	-15	14.31		
P60-330	.92	-15	14.00		
P60-331	.90	-15	14.18		
P60-340	.88	-15	14.62		
P60-341	.90	-15	13.75		
			Avg. 14.17	.87	±.32
P60-317	.86	0	13.88		
P60-318	.90	0	14.44		
P60-319	.86	0	13.69		
P60-334	.86	0	13.94		
P60-335	.90	0	16.06		
			Avg. 14.40	2.37	±.97
P60-320	.86	15	13.31		
P60-321	.90	15	15.38		
P60-322	.90	15	14.00		
P60-336	.86	15	14.88		
P60-337	.86	15	14.06		
			Avg. 14.33	2.07	±.81
P60-323	.86	30	12.69		
P60-324	.88	30	12.31		
P60-325	.90	30	12.56		
P60-338	.86	30	13.31		
			Avg. 12.72	1.00	±.43
P60-326	.90	45	9.81		
P60-327	.90	45	10.38		
P60-328	.92	45	11.75		
			Avg. 10.65	1.94	±1.00

Notes:
1. Cones assembled in DRC505-1 test bodies, plugs and rings (No. 2).
2. Loaded at Ravenna Arsenal, BAT Lot No. 30, with Composition B from Holston Lot No. 4-1197.
3. All rounds were tested at a standoff of 5.35 inches (75/105 x 7.5 inch).

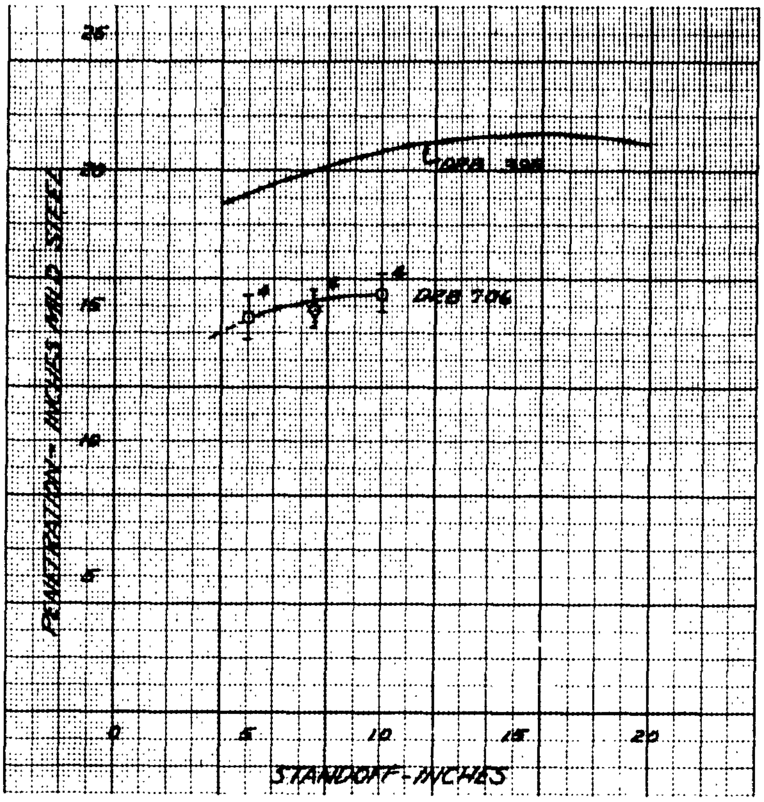


Fig. 4. Penetration Versus Standoff.
Effect of Cone Size.

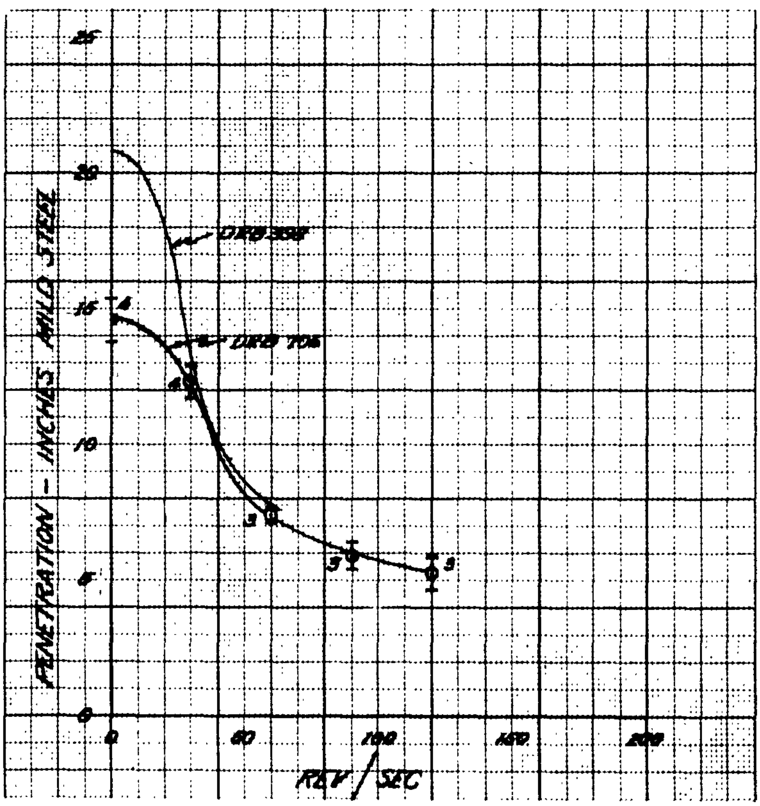


Fig. 5. Penetration Versus Rotation.
Effect of Rotation on 75 mm. and 105 mm. Cones.

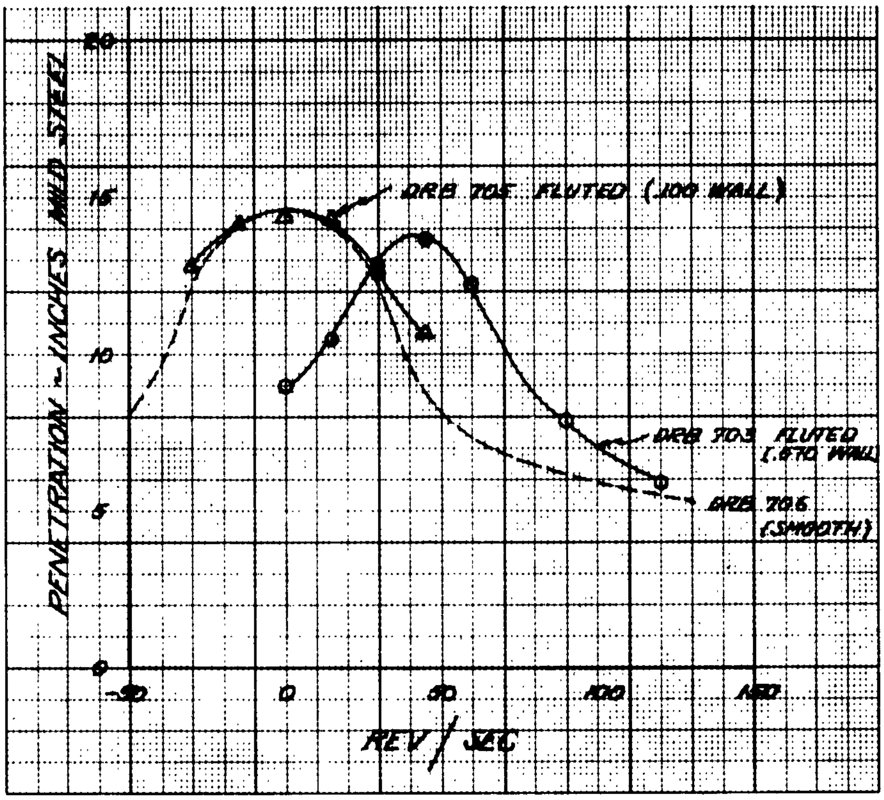


Fig. 6. Penetration Versus Rotation.
Effect of Wall Thickness.

Double Body Projectile

The evaluation of various types of bearing systems for possible use in double body projectiles has continued. The tests reported here are for tapered roller bearings. The tapered bearings are of conventional type and include both cageless and caged types. The test projectile assemblies are shown in Figs. 7 to 9. The projectiles were fired from a modified T19 rifle at a nominal muzzle velocity of 1700 fps and this velocity imparts a spin rate of 240 rps to the rotated or driven member. The spin rate of the now rotated member was determined in the usual fashion of firing through successive wire screens into a recovery box. Each screen has a characteristic grid pattern and the amount of rotation between successive screens can be determined from a study of the recovered projectile. Tables XI and XII are the firing records for these tests.

The results of these tests are summarized in the following tabulation:

Round	Spin Rate of N.R. Body	
	RPS	Cal/Rev
DB28	186	25
DB29	148	31
DB30	31	149
DB31	27	171
DB32	68/150/233	71/32/23
DB33	28/113/199	169/43/25

Since only two screens left engraving on projectiles DB32 and DB33 it is not possible to establish which of the possible spin rates is the correct one. Since this bearing is about the same as that used in DB28 and DB29 it is thought that the most likely spin rates for DB32 and DB33 are 150 and 113 rps, respectively.

The bearing systems of all projectiles except DB31 were recovered and examined. Figs. 10 to 13 show photographs of the recovered bearings. As in earlier studies with ball bearings it is evident that bearing cages lock the balls or rollers and prevent the proper functioning of the bearing. The cageless roller bearing system, Timken #T127, although rated for the smallest speed was the only one of the three which was satisfactory, but even this does not appear to be as satisfactory as the DRC 389 ball bearing assembly.

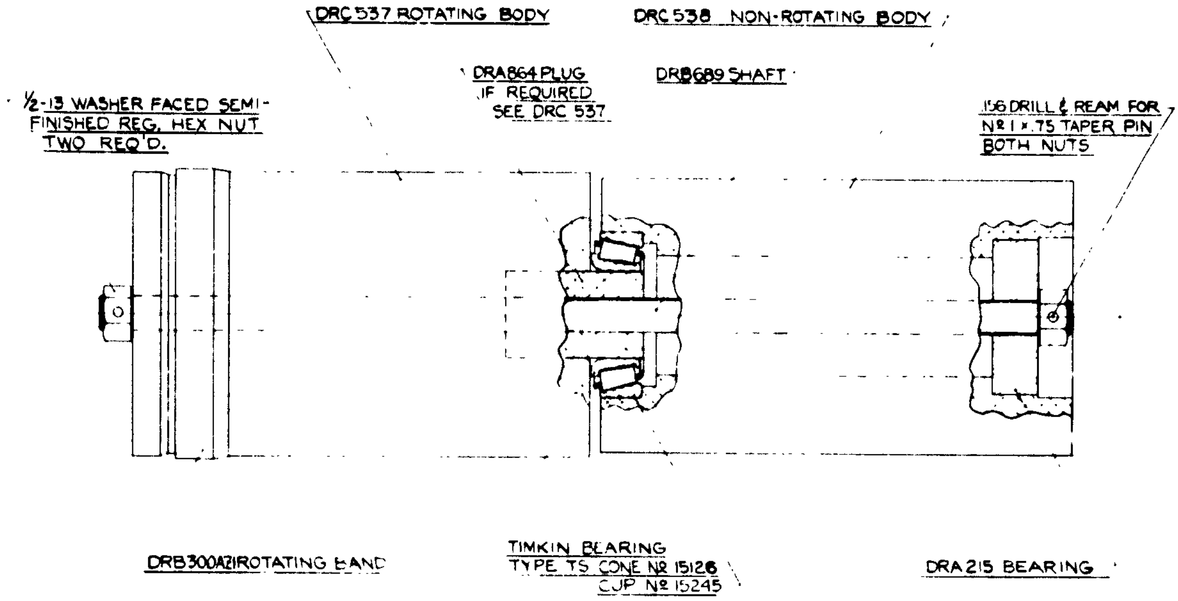


Fig. 7. Double Body Test Assembly.
Firestone Dwg. No. DRC536.

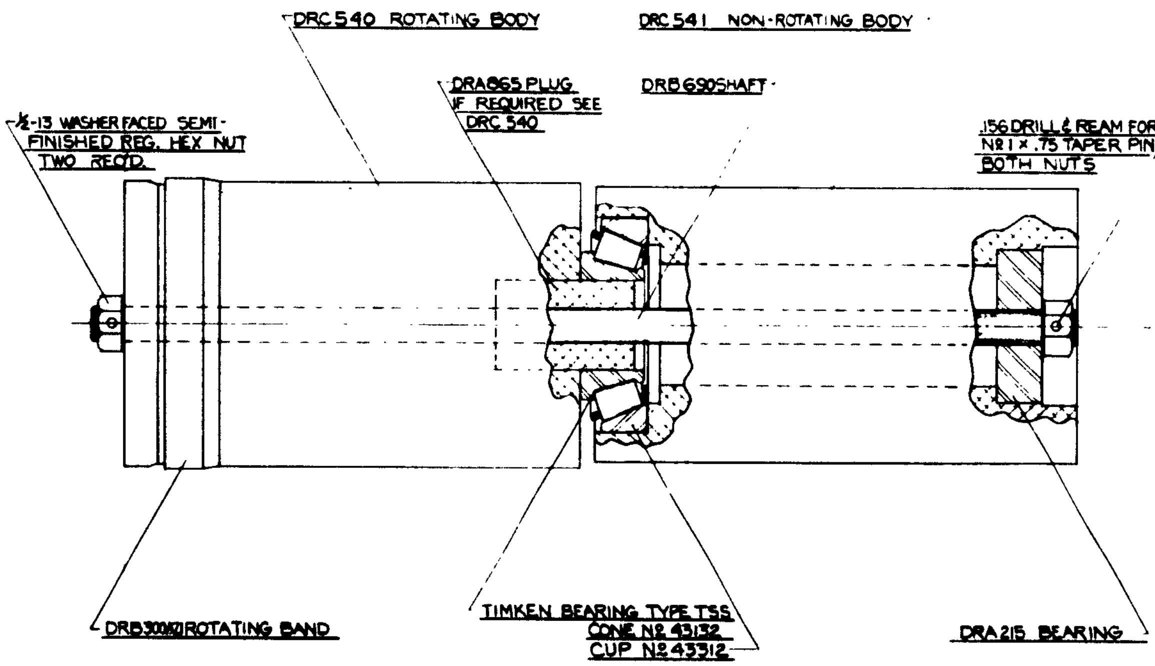


Fig. 8. Double Body Test Assembly.
Firestone Dwg. No. DRC539.

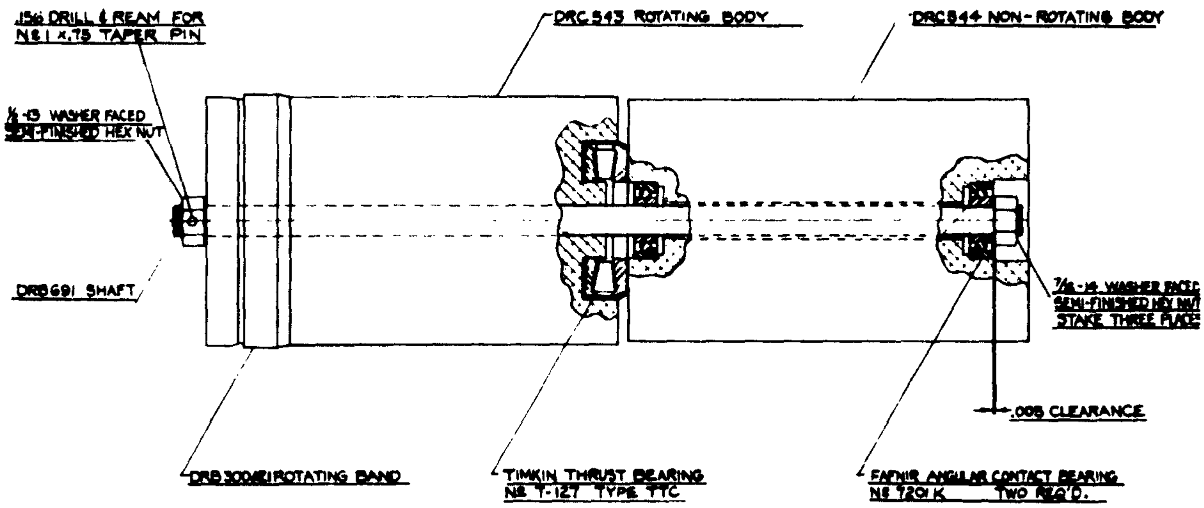


Fig. 9. Double Body Test Assembly.
Firestone Dwg. No. DRC542.

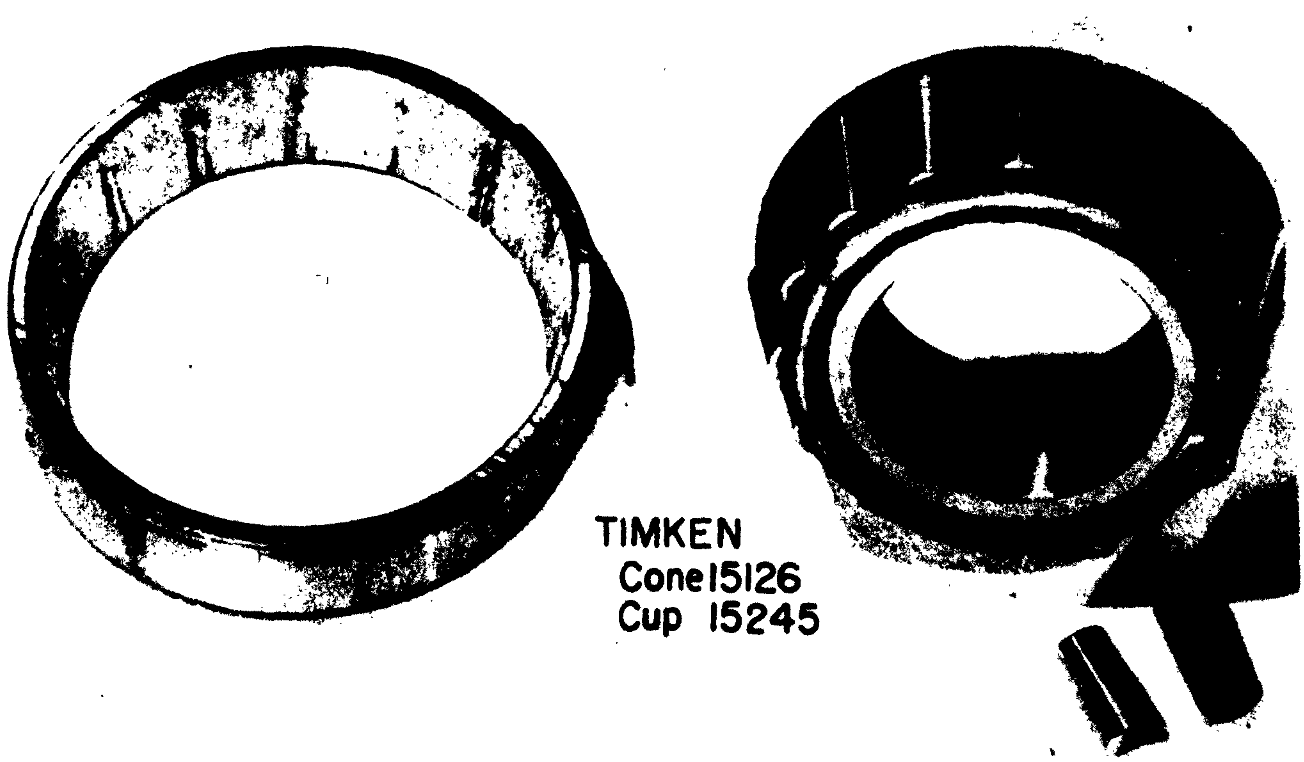


Fig. 10. Recovered Bearing System.
Double Body Projectile.

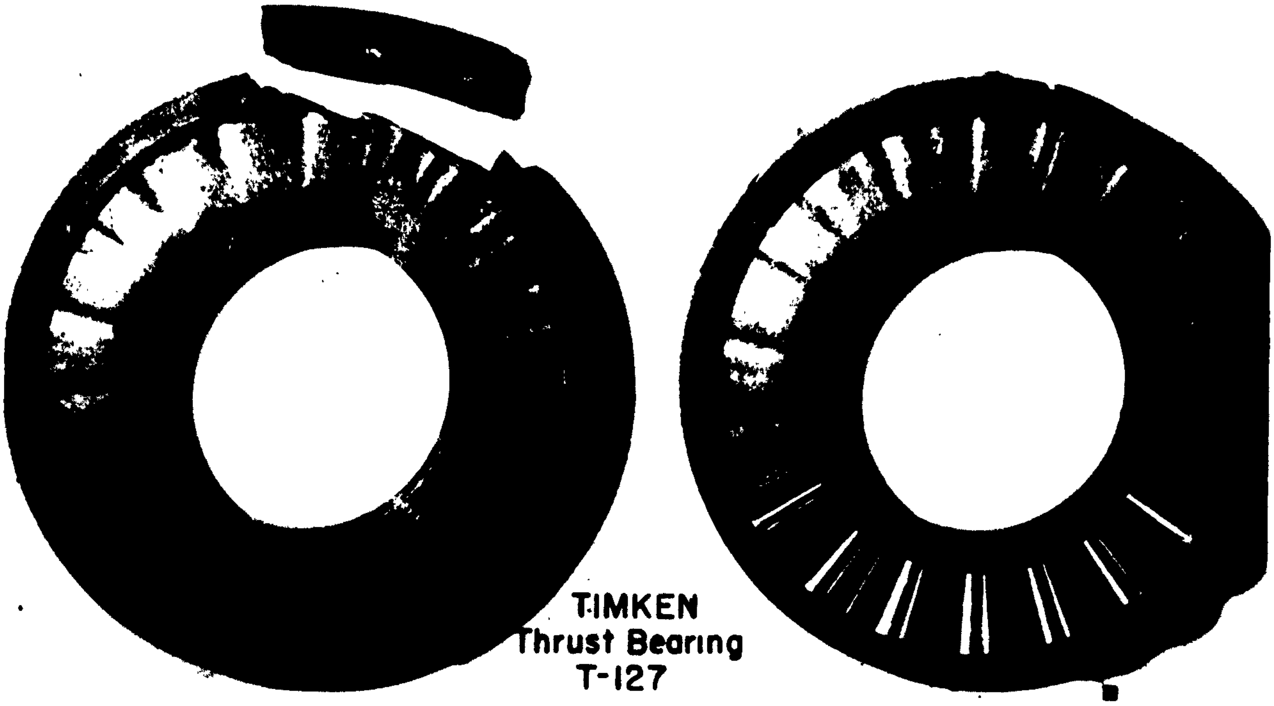


Fig. 11 Recovered Bearing System.
Double Body Projectile.

Fig. 12. Recovered Bearing System.
Double Body Projectile.

Fig. 13. Recovered Bearing System.
Double Body Projectile.

Future Program

1. Serrated Liners

a. Scaling Studies: DRD267, 60 flute cones cut off to 90mm size (3.00-in.base dia x .087-in.wall).

b. Effect of Index Angle. Two lots of cones of the DRD78 type described in the Supplement to the Thirty-Fourth Progress Report having index angles of 5° and 20°, and having minimum wall thicknesses of .100 in.are being manufactured.

c. DRD433 item 1 and item 2 cones (index angle 6° and 2° respectively) are being manufactured. These cones have 50 "matching" flutes .034 in.deep at the base datum and a wall thickness of .100 in.

d. DRD429 item 2. These cones have 16 "matching" flutes .034 in.deep at the base datum and a wall thickness of .100 in. Index angle is 6°. Flute orientation is the reverse of DRD78.

e. DRD434 item 2. Same as d except flute depth is .060 in.

2. Double Body Projectiles

a. Test actual double body projectiles for spin rate and flight behavior.

b. A series of projectiles are to be fired to determine the minimum wall thickness required for the non-rotated body, and also for the tee or boom.

c. Evaluation of additional ball bearing systems.

Table XI
Range Data
Aluminum Double Body Projectile
Fired Into Recovery Box

Gun — 108' — 1st. Screen — 7' — 2nd. — 20' — 3rd. — Recovery Box

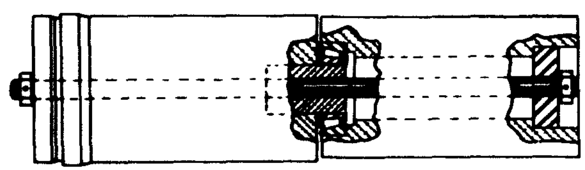
Purpose of Test Rotation of T120 projectiles
Program F1A6

PROJECTILE
Model T120
Type Alum double-body
Weight 18.10 lbs.
Retardation Factor = 0.4 ft/sec./ft.
Bourrelet Dia. 4.132 -.002
Special Features Timken Cone #15126
Timken Cup #15245
Timken T-127

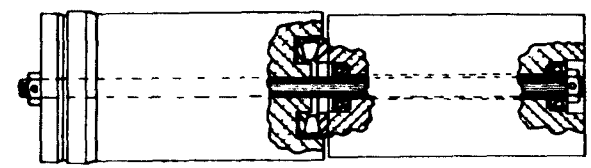
TEST GUN
Model T19
Type 105mm Recoilless
Serial No ———
Bore Dia. (Lands) 4.134 +.001
Bushing (Vent) VA884, #7230826
Tube 106 in, 1 in 20 Twist
Sighting Equipment Elbow Telescope
Mount
Type Pendulum
Constant 2.85 lbs-sec/in

MISCELLANEOUS DATA
Range Fired into recovery box
Propellant
Type MP M10 Web .0335 Weight 8 lbs.
Lot No. PA 30239
Primer ———
Shell Case T-6
Liner Polyethylene
Temperatures
Magazine Max 75°F. Min 75°F. Present 75°F.
Loading Room 70°F. Ambient ———

Round No.	Proj. No.	Proj. Weight (lb.)	Powder Charge (lb-oz)	Wind Vel. & Dir.	Chamber Pressure (lb/sq.in)	Muzzle Velocity ft/sec Instr	Muzzle Velocity ft/sec Actual	Elev (mils)	Angle of Rotation (degrees) Screen 1-2	Angle of Rotation (degrees) Screen 2-3	Rev per Sec Screen 1-2	Rev per Sec Screen 2-3	Rev per Sec Screen 1-3	Recoil (in)	Observations
4405	DB-29	18.10	8-0	—	10,800	—	—	—	235°	675°	147.5	147.8	147.65	14" Rear	
4406	DB-31			—	10,500	1590	1622	—		[illegible]		[illegible]		6½" "	Recovered in two pieces
4407	DB-30			—	10,800	1595	1617	—	54.5°	128°10'	34.2	28.1	31.15	12¾" "	
4408	DB-28			—	11,300	1608	1640	—	307°	843	185.4	186.1	185.8	15½" "	



TIMKEN
CONE 15126 CUP 15245



TIMKEN T-127

Proof Director E. Huffman
Observers P. Ginge
M.E. Toohig
Signed W.A. Brown

Table XII
Range Data
Aluminum Double Body Projectile
Fired Into Recovery Box

Gun — 96.84' — 1st Screen — 6' — 2nd — 20' — 3rd — Recovery Box

Purpose of Test: *Rotation of T120 projectiles*
Program: *F1A6*

PROJECTILE
Model: *T120*
Type: *Alum. double-body*
Weight: *18.71 lbs.*
Retardation Factor: *0.4 ft/sec./ft.*
Bourrelet Dia.: *4.132 −.002*
Special Features: *Timken Cone #43132*; *Timken Cup #43312*

TEST GUN
Model: *T19*
Type: *105mm Recoilless*
Chamber: *T19, #6, (26694-1-12938*
Bore Dia. (Lands): *4.134 +.001*
Bushing (Vent): *R 7230826*
Tube: *T19, 106 in., 1 in 20 Twist*
Sighting Equipment: *M17 Adapted Telescope*
Mount
Type: *Pendulum*
Constant: *2.25 LBS-SEC/in.*

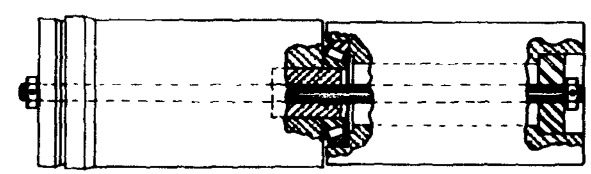
MISCELLANEOUS DATA
Range: *Fired into Recovery Box*
Propellant
Type: *MPM10* Web: *.0335* Weight: *8 lbs. 3 oz.*
Lot No.: *PA 30246*
Primer: *M57*
Shell Case: *T6*
Liner: *T6 polyethylene*
Temperatures
Magazine
Max: *70°F* Min: *70°F* Present: *70°F*
Loading Room: *72°F* Ambient: *39°F*

Round No.	Proj. No.	Proj. Weight (lb.)	Powder Charge (lb-oz)	Wind Vel. & Dir.	Chamber Pressure (lb/sq in)	Muzzle Velocity ft/sec Instr	Muzzle Velocity ft/sec Actual	Elev (mils)	Angle of Rotation (degrees) Screen 1-2	Angle of Rotation (degrees) Screen 2-3	Rev. per Sec. Screen 1-2	Rev. per Sec. Screen 2-3	Rev. per Sec. Screen 1-3	Recoil (in)	Observations
4500	Slug	T/38	7 - 13	—											Forward indicator kicked off
4501	DB-32	18.71	8 - 3	—	12,100 / 12,300	1655	1699	4¼	83° *	294°	—	67.5	67.5	14½"F.	Recovered as single unit
4502	DB-33	18.71	8 - 3	—	12,000 / 11,700	1615	1659	4¼	—	123.5°	—	[illegible]	—	20"F.	Recovered (Sheared shaft)

Note: Rounds were loaded and fired as single units without wadding.
Average velocity between the screens was used in spin calculations.

* This is a probable rotation. The angle of rotation between Screens #1 & 2 for DB-32 & 33 could not be measured.

Screen Data:
Three wire screens were used; 1/64 in. wire on 1st screen; 1/32 in. wire on 2nd Screen; 1/16 in. wire on 3rd. Screen.
Wire on all screens spaced West to East - ½ in - 1 in - 2 in.
Tinfoil was placed over the first and third screens to be used for shorting screens. This resulted in poor engraving of the first screen on the projectile.



TIMKEN—CONE 43132 CUP 43312

Proof Director: *E. Huffman*
Observers: *P. Gingo*
Signed: *O. Miller*

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